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**Joint contribution of rotation of the back and repetitive movements to disability pension
using job exposure matrix data**

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ABSTRACT

Background: Heavy physical effort at work has been linked with disability pension, but the contribution of other ergonomic job exposures is less studied. We studied the independent and joint contributions of long-term exposure to 1) rotation of the back and 2) repetitive movements to disability pension, particularly due to musculoskeletal disorders.

Methods: Exposures were measured with the Helsinki Health Study Job Exposure Matrix during 1996-2005 and linked to register data on employees of the City of Helsinki, Finland (n=18 585). Outcomes were followed up during 2006-2015. Competing risk survival analyses were performed and synergy indices computed, adjusting for sociodemographic factors.

Results: Long-term exposure to rotation of the back was associated with disability pension due to any cause (age and sex -adjusted subhazard ratio [SHR] 2.39, 95% confidence interval [CI] 1.73-3.30), and specifically disability pension due to musculoskeletal disorders (SHR=3.39, 95% CI 1.52-7.56) when compared to employees exposed to neither of the two exposures. Repetitive movements alone did not increase the risk of disability pension (all-cause SHR=1.08, 95% CI 0.84-1.38, musculoskeletal SHR=1.65, 95% CI 0.91-2.97). Employees with exposure to both rotation of the back and repetitive movements had the highest risk of disability pension due to musculoskeletal disorders (SHR=5.98, 95% CI 3.85-9.28), but the interaction between exposures was additive rather than synergistic. Adjustment for education diluted the associations by 42-108%.

Conclusion: Long-term exposure to awkward work postures increased the risk of disability pension. Educational inequalities largely account for differences in occupational exposures.

Keywords: back rotation; follow-up study; job exposure matrix; repetitive movements; work disability

INTRODUCTION

Rotative postures and repetitive movements are important occupational risk factors for musculoskeletal disorders.^{1, 2} More specifically, repetitive movements are a known risk factor for osteoarthritis,³ and neck and shoulder pain among women.⁴ Postures involving rotation are also among biomechanical risk factors for low back pain.^{5, 6} The evidence regarding the association between physically demanding work and disability pension is rather robust.⁷⁻¹² Some previous studies have found that this association is particularly robust with disability pension due to musculoskeletal disorders, while no association with disability pension due to mental disorders was observed.^{7, 8, 13}

The risk of disability pension varies widely between occupations, indicating that work characteristics are important determinants of disability pension.¹⁴ Thus, knowledge about these specific risk factors is needed for designing areas of intervention. A study in Danish employees found that repetitive work was associated with a higher risk of disability pension,¹⁵ but the length of exposure was not considered. Another Danish study found that retrospectively evaluated exposure to working with the back severely bended or twisted increased the probability of disability pension, but no association was observed for occupational exposure to repetitive movements.¹⁶ The Danish studies did not study cause-specific disability pension.

There have also been other limitations in previous studies. Exposure has typically been measured at one time point only,^{7, 17, 18} whereas the contribution of the long-term exposure to the risk of disability pension is less studied. Yet another gap in the research evidence exists in examining the joint associations of different exposures. Combined exposure to a set of awkward postures may have

more adverse health consequences than exposure to a single awkward posture. Studying whether single and combined exposures differ in their association to health and work disability may have important implications for practice. Thus, we examined how long-term (8-10 years) exposure to rotation of the back and repetitive movements independently and jointly contribute to the risk of disability pension due to any cause and specifically due to musculoskeletal disorders over a 10-year follow-up.

METHODS

Study population

The study population included all employees of the City of Helsinki between 1996 and 2005 (n=105 456). For this cohort, we had employer's register data, including employees' occupational titles. Exposure data were from job exposure matrix developed for this population.¹³ Using national personal identification numbers, we were also able to link register data from the Finnish Centre for Pensions covering all granted pensions based on disability including ICD-10 coded diagnoses,¹⁹ as well as old age pensions. In addition, we linked information on age, sex, education, and all-cause mortality from the Statistics Finland.

The linkage of exposure estimates (at least for one out of ten study years) succeeded for a total of 98 690 employees. From this cohort, the eligible population were those who were alive and not on disability or old age pension before 1st January 2006 (n=87 531). To study long-term exposure, we omitted employees for whom we did not have information on exposures for at least 8 out of 10

years (n=66 222). Moreover, we omitted those without information on covariates (n=2724) resulting in 18 585 employees for our final analytical sample.

Exposure

The exposure estimates were based on the Helsinki Health Study Job Exposure Matrix (HHS-JEM), described in more detail elsewhere.¹³ In short, the HHS-JEM is based on the Helsinki Health Study data from 2000-2002 among employees of the City of Helsinki, Finland.²⁰ In the HHS survey, the participants reported whether rotation of the back and repetitive movements were present in their work. The scale was: 0 (does not occur); 1 (occurs, but does not bother); 2 (occurs, and bothers to a moderate degree); 3 (occurs, and bothers to a large degree). Value 0 was categorized as “unexposed”, and all the other values as “exposed”. This information was then aggregated to represent the prevalence of each exposure based on occupational title. The estimates were calculated separately for men (n=1381) and women (n=5378) and presented as the prevalence of exposures (as percentages) in each occupational title. The minimum number of respondents for whom the JEM estimates were calculated was 18 for men, and 24 for women.

We followed occupational exposures for 10 years, from January 1, 1996 through December 31, 2005. The annual exposure was computed into mean exposure during the exposure follow-up time of 8 to 10 years (percentage). Mean exposure estimates were dichotomized: If at least 50% of employees in an occupation were exposed, then the exposure estimate was set at 1, and otherwise at 0. Dichotomization was done to calculate 2×2 combination variable of ‘exposure to neither rotation of the back nor repetitive movements’, ‘exposure only to rotation of the back’, exposure only to repetitive movements’, and ‘exposure to both’. Similar dichotomization has been used in an earlier

job exposure matrix ²¹. Those with no exposure to either of the workload factors were used as the reference group in later analyses.

Outcomes and competing events

In Finland, a sickness absence benefit can be granted for a maximum of one year. After that, if the person's work ability remains reduced at least by 60% (remains unable to work), a full disability pension can be granted. The decision on granting a disability pension is based on a physician's certificate and a medical diagnosis and is made by an insurance institution. In addition to disability pension due to any cause, we examined disability pension due to musculoskeletal diseases (M00-M99), which cover about 30% of all granted disability pensions.²² Date of death since 2006 was retrieved from Statistics Finland register of causes of death. The outcome follow-up was 10 years, from January 1, 2006 until December 31, 2015.

Covariates

Age and educational level were obtained from Statistics Finland. Age was used as a continuous variable. Educational level was classified into 0 (secondary education or less); 1 (tertiary education, undergraduate); 2 (tertiary education, graduate/doctoral degree).

Statistical analysis

For general description of the data, we used frequency tables, chi squared tests, means and standard deviations. We tested effect modification of sex by including interaction term 'sex ×

exposure' into Cox proportional hazards models. In all models the interaction terms were non-significant ($p > 0.05$), and analyses were therefore conducted in pooled data.

We modelled cumulative incidence curve (CIC) to compare time to disability pension for the three exposed groups and the unexposed group. CIC breaks down the probability of ending up on disability pension between all the events of interest (=competing risks). Grey's test was used to check if CICs were similar at all time points ($p < 0.001$ indicates that they were not).²³

We used Cox proportional hazards models to examine the association between cumulative exposures and disability pension due to any cause, and specifically due to musculoskeletal disorders. We defined death and disability pension due to other than musculoskeletal diagnosis as competing event to disability pension due to musculoskeletal disorders. Cases were censored in the event of old-age pension, or when reaching the age of 63 after which disability pension can no longer be granted, or at the end of the follow-up. The model of competing risks produces subhazard ratios (SHR) with 95% confidence intervals (CI). Compared to the standard survival analysis, where the follow-up of non-events terminates only due to censoring, competing risk analysis considers competing events that prevent the event of interest from occurring. Treating observations that experience competing events as if they could later experience the event of interest overestimates the probability of failure, and the bias is larger when the competition due to frequent competing events is heavier.^{24, 25}

The contribution of education was determined by calculating the percentage reduction in the parameter coefficient (Beta[β]) for the association between exposure and disability pension after the inclusion of education as a covariate using the formula:

$$100 \times (\beta_{\text{Model 1}} - \beta_{\text{Model 2}}) / (\beta_{\text{Model 1}}).$$

We computed synergy indices to examine whether the joint effects of the two occupational exposures were additive or synergistic (i.e., the presence of biological interaction).²⁶ Synergy Index (SI) measures the deviation from an additive model.^{27, 28} If there is no biological interaction, SI=1. An additive effect occurs when two exposures act independently, where synergistic effects refers to effect that is more than the sum of the two exposures.

As a sensitivity analysis, we adjusted for chronic diseases present at the start of the follow-up as outlined in **Supplementary Table 1**. All analyses were conducted using SAS version 9.4.

RESULTS

Of the participants (n=18585), 68% had a long-term occupational exposure to both rotation of the back and repetitive movements. These participants were more often women and had a lower level of education. 13% had long-term exposure to repetitive movements only, and only three percent had a long-term exposure to rotation of the back only. Exposure to rotation of the back only was more prevalent among men. Exposure to repetitive movements only was more prevalent among women. The mean age was highest among those with long-term exposure to repetitive movements only. The prevalence of chronic disease was highest among employees with exposure to rotation of the back only. A total of 16% were exposed to neither rotation of the back nor repetitive movements. These participants were more often men and had a higher level of education. (**Table 1.**)

Table 1. Characteristics of the participants by cumulative occupational physical exposure to rotation of the back and/or repetitive movements.

	Exposure to neither n=2980 (16%)			Exposure to rotation of the back only n=606 (3%)			Exposure to repetitive movements only n=2366 (13%)			Exposure to both n=12633 (68%)		
	%	Mean	SD	%	Mean	SD	%	Mean	SD	%	Mean	SD
Women	26			40			57			76		
Men	74			60			43			26		
Secondary education or lower	6			53			18			53		
Tertiary education/undergraduate	25			41			38			39		
Tertiary education/graduate	69			6			44			9		
Age (at the beginning of the follow-up)		48.8	8.3		44.7	7.8		50.2	8.6		46.6	8.5

During the 10-year follow-up, a total of 5% of those with neither of the examined long-term exposures ended up on disability pension, while the corresponding percentage was 12 for those with exposure to both rotation of the back and repetitive movements, 9% for those with exposure to the rotation of the back only, and 6% for those with repetitive movements only (**Fig. 1**). The SHR for all-cause disability pension adjusted for sex and age was 2.39 (95% CI 1.73-3.30) for those with exposure to rotation of the back. Exposure to repetitive movements only was not associated with all-cause disability pension (SHR 1.08, 95% CI 0.84-1.38). For those with both exposures, the SHR was 2.28 (95% CI 1.91-2.73) compared to those without either exposure. The SI was 0.88 (95% CI 0.53-1.47) indicating that the two exposures acted independently in relation to all-cause disability pension. With additional adjustment for education, the estimates diluted by 49-108%. (**Table 2.**)

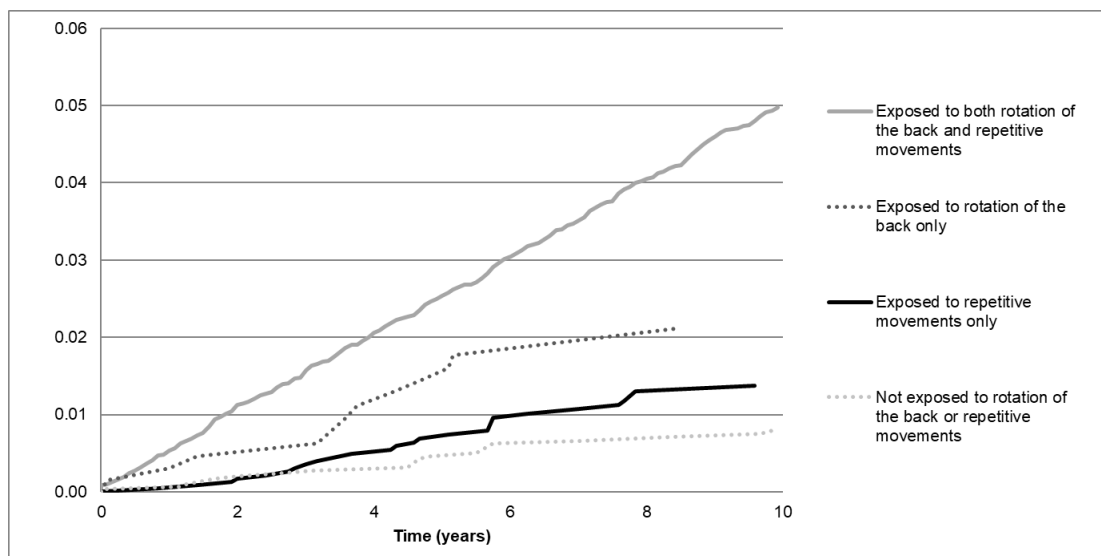


Figure 1. Cumulative incidence of all-cause disability pension during the follow-up, stratified by long-term occupational exposure to rotation of the back and/or repetitive movements. Gray's test for equality of cumulative incidence functions $p < 0.001$.

We then studied disability pension due to musculoskeletal disorders as the outcome. During the 10-year follow-up, less than 1% of those with neither of the occupational exposures ended up on

disability pension, while the corresponding percentage was 5% for those with exposure to both rotation of the back and repetitive movements, and 1-2% for exposure to only one of the two exposures (**Fig 2**). After adjustment for sex and age, those exposed to both rotation of the back and repetitive movements had a 5.98 (95% CI 3.85-9.28) times higher risk of disability pension due to musculoskeletal disorders than those exposed to neither. For exposure to rotation of the back only, the SHR was 3.39 (95% CI 1.52-7.56), and exposure to repetitive movements only was not associated with disability pension due to musculoskeletal disorders (SHR 1.65, 95% CI 0.91-2.97). The SI was 2.34 (95% CI 0.39-14.05), which indicates an additive rather than synergistic effect of the two exposures. Additional adjustment for education diluted the estimates by 42-66%, and the association between rotation of the back and disability pension due to musculoskeletal disorders was no longer statistically significant. (**Table 2.**)

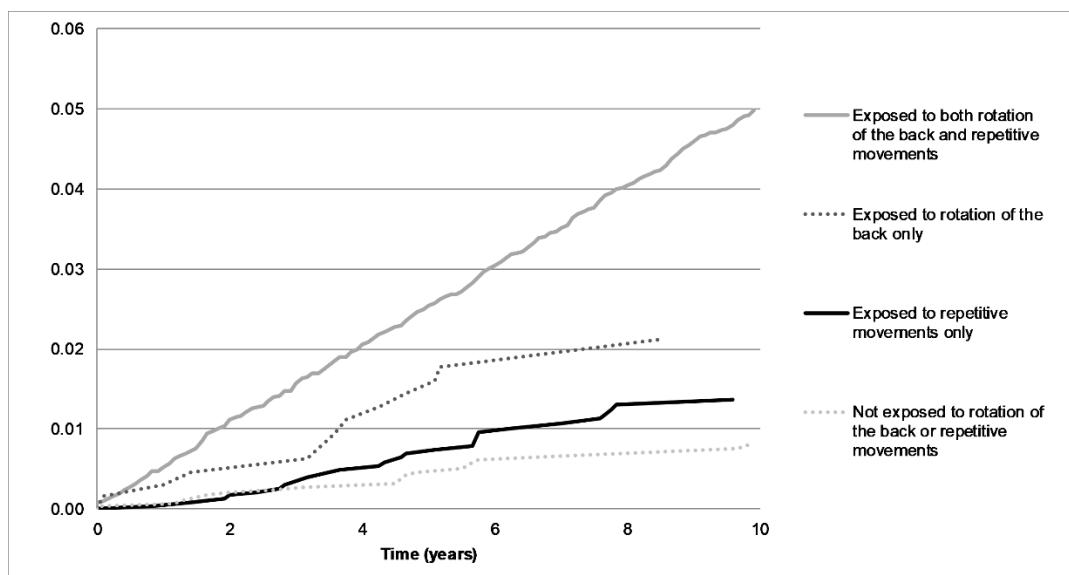


Figure 2. Cumulative incidence of disability pension due to musculoskeletal disorders stratified by long-term occupational physical exposure to rotation of the back and/or repetitive movements. Gray's test for equality of cumulative incidence functions $p < 0.001$.

Table 2. Subdistribution hazards (SHR) with 95% confidence intervals for each outcome by cumulative occupational physical exposure to rotation of the back and/or repetitive movements while adjusting for age and sex and following adjustment for education (=mediating factor).

	All-cause disability pension ^a					% Attenuation	Disability pension due to musculoskeletal disorders ^b					% Attenuation
	n of events/n of cases (%)	SHR ^c	95% CI	SHR ^d	95% CI		n of events/n of cases (%)	SHR ^c	95% CI	SHR ^d	95% CI	
Exposure to neither	141/2980 (5)	1		1			21/2980 (0.7)	1		1		
Exposure to rotation of the back	51/606 (8)	2.39	1.73-3.30	1.56	1.11-2.18	49	9/606 (1.5)	3.39	1.52-7.56	1.51	0.67-3.43	66
Exposure to repetitive movements	114/2366 (5)	1.08	0.84-1.38	0.94	0.74-1.21	108	25/2366 (1.1)	1.65	0.91-2.97	1.25	0.70-2.24	54
Exposure to both	1224/12633 (10)	2.28	1.91-2.73	1.52	1.25-1.85	49	484/12633 (3.8)	5.98	3.85-9.28	2.80	1.75-4.46	42
Synergy Index		SI ^a	95% CI	SI ^b	95% CI			SI ^a	95% CI	SI ^c	95% CI	
		0.88	0.53-1.47	1.04	0.37-2.94			1.64	0.70-3.86	2.34	0.39-14.05	

^a All-cause: 1530 events of interest, 1516 competing events (old-age pension/death), 15383 censored

^b Musculoskeletal disorders: 539 events of interest, 2179 competing events (disability pension due to other diagnoses/old-age pension/death), 15711 censored

^c Adjusted for sex and age

^d Adjusted for sex, age, and education

In sensitivity analyses, we further adjusted the statistical models for chronic disease morbidity. In these models presented in **Supplementary Table 1**, neither of the exposures alone were associated with all-cause or musculoskeletal disorder -related disability pension. Having both the exposures was associated with both all-cause (SHR 1.46, 95% CI 1.19-1.78) and musculoskeletal (SHR 2.74, 95% CI 1.72-4.38) disability pension.

DISCUSSION

We examined whether long-term occupational exposure to rotation of the back and repetitive movements independently and jointly contribute to the risk of disability pension. In our study population, the most prevalent group were those with both exposures (68%). Exposure to only one of the two exposures was more infrequent (13-16%), and exposure to neither was very infrequent (3%). This shows that our analytic sample consists mainly of employees in manual occupations, and less of those in non-manual occupations. This was reflected in vast differences in level of education between those exposed to both exposures (9% with tertiary education) and those exposed to neither (69% with tertiary education).

Adjustment for education mediated the associations between exposure groups and outcomes by 42-108%. As occupational position is strongly driven by level of education, adjusting for education when studying occupational exposures may be considered as overadjustment. Thus, we report sex- and age-adjusted models as main results and conclude that educational inequalities largely mediate this association.

Exposure to rotation of the back was associated with higher risk disability pension due to any cause, and specifically due to musculoskeletal disorders. With all-cause disability pension, the joint association of the two exposures was mainly driven by exposure to rotation of the back. For disability pension due to musculoskeletal disorders, the main finding was that the risk was highest among those with long-term exposure to both rotation of the back and repetitive movements. While the SI indicated a synergistic effect, the 95% confidence intervals for the SI were very wide thus leaving the synergistic effect unconfirmed. We conclude that the joint association was not synergistic in the sense that the effect of the two exposures taken together would have been greater than their additive independent effects.

To our knowledge, this was the first study to examine the independent as well as the joint associations between long-term exposure to awkward work postures and disability pension, particularly due to musculoskeletal causes. A previous Dutch study stratified the exposure by the level of exposure, and found that flexion and rotation of the trunk and lifting at work were related to low back pain, especially at greater levels of exposure.⁵ That study, however, could not separate the effect of flexion and rotation from the effect of lifting at work. As our sample size was considerably larger, we could study the independent effects as well as the joint effect. Also, studies that have found an association between ergonomic work environment factors and disability pension, have not been able to separate between independent and joint effects.^{11, 15, 16}

Additional strengths of the study were the follow-up time for both exposure and outcome. All measures, that is, exposure, covariate, and outcome measures, can be viewed as rather objective measures, as exposure was based on JEM-estimates (aggregated survey data), and the outcomes were based on reliable and complete register data. The data on covariates were also register-based. The linkage of HHS-JEM-estimates to register data succeeded for 94% of all the employees of the

City of Helsinki. A further strength in our study was that we studied the diagnosis behind disability pension, and found that awkward work postures were particularly associated with an increased risk of disability pension based on musculoskeletal disorders, congruent to earlier studies.^{7, 8}

Despite the strengths the study also has some limitations. Our focus on long-term exposure meant that we had to omit all participants with less than 8 years of exposure information. Thus, our final sample represented 21% of the eligible population. This may have resulted in health selection of only the fitter and healthier workers who remained employed with the City of Helsinki, and cause underestimation of the true effects. Moreover, aggregate measures such as JEM, are not able to tap within-job and individual variance in exposures, which could either inflate or deflate the estimates. However, previous JEM validation studies have found that these matrixes have rather good validity, sensitivity and specificity, particularly regarding physical exposures.^{21, 29}

We were unable to study the effects of various lengths of exposure, as the exposures were based on the average exposure for 8-10 years and dichotomized into prevalence of <50% and ≥50% in an occupation. We decided to focus on long-term exposure, as earlier research has showed the association in shorter follow-ups.^{7, 15} The exposures were rather stable throughout the 10-year follow-up: if a person had been exposed to repetitive movements or rotation of the back at first year of the follow-up, that person most probably was exposed also at last follow-up year. This means that very few people changed from more strenuous to less strenuous work (or the other way around), indicating that even with different exposure definitions, we might not have been able to study various lengths of exposure. Moreover, it may be possible to change to less strenuous work within the same occupational title (i.e., work modification). As our exposure estimates were based on occupational titles, we were unable to account for this kind of change. An earlier Danish study used retrospective survey evaluations about whether the respondent had been exposed and for how

many years.¹⁶ However, this kind of approach is prone to recall bias of both exposure time and of the actual occupational exposures.

We did not have information on psychosocial factors at work as psychosocial JEMs have been shown to have relatively low validity.³⁰ In previous studies, adjusting for psychosocial factors have somewhat diluted the effects, but the associations between working with the back severely bended/twisted¹⁶ and repetitive work (for women)¹⁵ and disability pension have been robust for adjustment for psychosocial factors at work. Not adjusting for psychosocial factors may have caused overestimating the true effect of awkward work postures. We decided to control for sex, age, and education. We conducted sensitivity analyses, where we additionally controlled for chronic diseases. We did not include chronic diseases as a covariate in the main analyses, since these diseases may have either preceded the exposures, or occurred later (after the exposure to awkward work postures), in which case adjustment for these conditions would be inappropriate.³¹

In conclusion, long-term joint exposure to rotation of the back and repetitive movements at work were associated with a higher risk of disability pension due to musculoskeletal disorders. The fact that we could differentiate between independent and joint effects of different types of awkward postures at work has important implications for practice. While it may not be possible to cut all adverse work postures, even reducing them may contribute to less work disability. This is highlighted in manual occupations, where these exposures are highly prevalent, and the risk of work disability due to musculoskeletal disorders is highest.

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Keypoints:

- Exposure to physically demanding work is linked with disability pension, particularly due to musculoskeletal disorders.
- We determined the independent and joint contributions of long-term (8-10 years) exposure to rotation of the back and repetitive movements to disability pension.
- Exposure to rotation of the back was associated with disability pension due to any cause and due to musculoskeletal disorders, but repetitive movements alone did not increase the risk.
- Employees exposed to both rotation of the back and repetitive movements had the highest risk of disability pension due to musculoskeletal disorders.
- While it may not be possible to cut all awkward work postures, even reducing them may contribute to less work disability.

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Supplementary Table 1. Subdistribution hazards with 95% confidence intervals for both outcomes by cumulative occupational physical exposure to rotation of the back and/or repetitive movements. Statistical models are adjusted for sex, age, education and chronic somatic disease^a.

	All-cause disability pension^b			Disability pension due to musculoskeletal disorders^c		
	n of events/n of cases (%)	SHR ^c	95% CI	n of events/n of cases (%)	SHR ^c	95% CI
Exposure to neither	141/2980 (5)	1		21/2980 (0.7)	1	
Exposure to rotation of the back	51/606 (8)	1.36	0.97-1.91	9/606 (1.5)	1.42	0.63-3.24
Exposure to repetitive movements	114/2366 (5)	0.90	0.70-1.15	25/2366 (1.1)	1.23	0.69-2.19
Exposure to both	1224/12633 (10)	1.46	1.19-1.78	484/12633 (3.8)	2.74	1.72-4.38
Synergy Index		SI ^a	95% CI		SI ^a	95% CI
		1.77	0.26-12.0		2.68	0.34-21.0

^a Chronic somatic conditions diagnosed 1-3 years before the start of the outcome follow-up: cancer, diabetes, cardiac failure, coronary artery disease, stage 2 hypertension, asthma, Parkinson's disease, epilepsy, uremia, bowel disease, multiple sclerosis, and diseases of pancreas (as defined through special medication reimbursement valid at the start of the outcome follow-up on 1st January 2006). In addition, we defined mental disorders from medication purchases with the Anatomical Therapeutic Chemical Classification (ATC) codes N05 (psycholeptics) and N06 (psychoanaleptics) during 2003-2005 (i.e., three years before the start of the outcome follow-up). The presence of chronic disease was defined as having at least one of these proxies for somatic or mental condition. Information on prescription medication purchases and special medication reimbursements were obtained from the Social Insurance Institution of Finland. Information regarding notifications of diagnosed malignant tumors were from the Institute of Statistical and Epidemiological Cancer Research (the Finnish Cancer Registry).

^b All-cause: 1530 events of interest, 1516 competing events (old-age pension/death), 15383 censored

^c Musculoskeletal disorders: 539 events of interest, 2179 competing events (disability pension due to other diagnoses/old-age pension/death), 15711 censored